PHILIPS

*Directions for use*

# DIGITAL MULTIMETER
# PM 2421

9447 024 21011

9499 470 04411 1/1268/1/01

IMPORTANT

In correspondence concerning this instrument, please quote the type number and serial number as given on the type plate at the rear of the instrument.

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# GENERAL

## I. INTRODUCTION

The PHILIPS Digital multimeter PM 2421 is a universal instrument with digital display for the accurate measurement of electrical quantities.

The instrument permits of measuring direct and alternating voltages in a level range of more than $1:10^7$. The frequency range in the case of alternating voltage measurements extends form 10 Hz to 1 MHz.
In conjunction with a measuring probe (optional) it is possible to carry out HF voltage measurements at frequencies up to 700 MHz.

Current and resistance measurements are possible with the PM 2421 in a range greater than $1:10^{10}$.

Range and mode selection is effected with the aid of simple and conveniently arranged push-buttons. An automatically controlled measuring range selector switches a voltage divider within 3 decades so that the most favourable display value is obtained. If desired, the range selector can also be operated manually.
The measuring data (polarity of the direct voltage, automatically selected range and the digital measuring quantity) are available from the memory in encoded digital form.
With the aid of an additional printed circuit board which can be plugged into the digital section, the digital information is converted into standard levels, thus enabling the connection of a printer or recorder.
Apart from the digital output signal a conventional analogue output signal is also available for continuous recording of the measuring quantity.

The circuit zero is isolated from the housing and from the mains by means of a double screening so that floating measurements are also possible.

The instrument is provided with integrated circuits and silicon semiconductors.
On account of its high sensitivity, its great accuracy and its rugged construction, the PM 2421 is suitable for research and development as well as for educational purposes, repair service, testing, general industrial applications etc.

## II. TECHNICAL DATA

Properties expressed in numerical values with tolerances are guaranteed by the factory. Numerical values without tolerances serve only for information and represent the properties of an average instrument.

### DIRECT VOLTAGE

| | |
|---|---|
| mV-ranges | |
| Full-scale values | 13.99 mV, 139.9 mV, 1399 mV |
| Resolution | 10 µV at the most sensitive range |
| Input resistance | 1 MΩ |
| V-ranges | |
| Full-scale values | 13.99 V, 139.9 V, 1000 V |
| Input resistance | 10 MΩ |
| Accuracy | |
| Relative to full-scale value | ± 0.1 % |
| Relative to reading | ± 0.1 % |
| A.C. rejection for frequencies ≥ 50 Hz | min. 80 dB |
| Overload protection in mV-range | max. 500 V d.c. |
| Overload protection in V-range | max. 1000 V d.c. |

### DIRECT CURRENT

| | |
|---|---|
| nA-ranges | |
| Full-scale values | 13.99 nA, 139.9 nA, 1399 nA |
| Resolution | 10 pA at most sensitive ranges |
| Accuracy | |
| Relative to full-scale value | ± 0.3 % |
| Relative to reading | ± 0.2 % |
| Voltage drop | 1 mV/nA |
| µA-ranges | |
| Full-scale values | 13.99 µA, 139.9 µA, 1399 µA |
| Accuracy | |
| Relative to full-scale value | ± 0.3 % |

| | |
|---|---|
| Relative to reading | ± 0.2 % |
| Voltage drop | 1 mV/μA |

mA-ranges

| | |
|---|---|
| Full-scale values | 13.99 mA, 139.9 mA, 1399 mA |
| Accuracy | |
| Relative to full-scale value | ± 0.3 % |
| Relative to reading | ± 0.2 % |
| Voltage drop | 1 mV/mA |

ALTERNATING VOLTAGE

mV-ranges

| | |
|---|---|
| Full-scale values | 13.99 $mV_{rms}$ 139.9 $mV_{rms}$ 1399 $mV_{rms}$ |
| Resolution | 10 μV at the most sensitive ranges |
| Preliminary indication with short-circuited input | max. 20 μV |
| Input impedance | 1 MΩ // 40 pF |

V-ranges

| | |
|---|---|
| Full-scale values | 13.99 $V_{rms}$ 139.9 $V_{rms}$ 500 $V_{rms}$ |
| Input impedance | 10 MΩ // 25 pF |

Accuracy

| | |
|---|---|
| 20 Hz - 300 kHz : Relative to full-scale | ± 0,3 % |
| Relative to reading | ± 0,2 % |
| 10 Hz - 20 Hz and 300 kHz - 1 MHz: Relative to full-scale | ± 1 % |

Measuring method

By means of full wave rectifier (for sinewave input voltages, calibrated in rms values)

Overload protection in mV-range

| | |
|---|---|
| At frequencies of ≤ 50 Hz | max. 300 $V_{rms}$ |
| At all other frequencies | max. 30 $V_{rms}$ |

| | |
|---|---|
| Overload protection in V-range | max. 500 $V_{rms}$ or 750 $V_p$ |

# ALTERNATING CURRENT

## nA-ranges

| | | |
|---|---|---|
| Full-scale values | | 13.99 nA, 139.9 nA, 1399 nA |
| Resolution at most sensitive range | | 10 pA |
| Accuracy | | |
| Relative to full-scale value in frequency range | 10 Hz - 50 Hz | ± 0.5 % |
| | 50 Hz - 100 Hz | ± 1 % |
| Relative to reading | | ± 0.5 % |
| Voltage drop | | 1 mV/nA |

## μA-ranges

| | | |
|---|---|---|
| Full scale values | | 13.99 μA, 139.9 μA, 1399 μA |
| Accuracy | | |
| Relative to full-scale value in frequency range | 10 Hz - 10 kHz | ± 0.5 % |
| | 10 kHz - 20 kHz | ± 1 % |
| Relative to reading in frequency range | 10 Hz - 10 kHz | ± 0.5 % |
| | 10 kHz - 20 kHz | ± 1 % |
| Voltage drop | | 1 mV/μA |

## mA-ranges

| | | |
|---|---|---|
| Full-scale values | | 13.99 mA, 139.9 mA, 1399 mA |
| Accuracy | | |
| Relative to full-scale value in frequency range | 10 Hz - 100 kHz | ± 0.5 % |
| | 100 kHz - 200 kHz | ± 1 % |
| Relative to reading in frequency range | 10 Hz - 100 kHz | ± 0.5 % |
| | 100 kHz - 200 kHz | ± 1 % |
| Voltage drop | | 1 mV/mA |

## H. F. VOLTAGES

| | |
|---|---|
| To be measured with probe PM 9203 | |
| Frequency range | 300 kHz...700 MHz |
| Full-scale values | 13.99 $mV_{rms}$ 139.9 $V_{rms}$ 1399 $mV_{rms}$ |
| Minimum measurable H. F. voltage | 2 mV |
| Deviation of frequency response between | |
| 500 kHz and 300 MHz | $\leq$ 0.5 dB |
| 300 MHz and 700 MHz | $\leq$ 1.5 dB |
| Accuracy at voltages > 5 mV | |
| between 500 kHz and 300 MHz | $\leq$ 1 dB |
| between 300 MHz and 700 MHz | $\leq$ 2 dB |
| Input capacitance | $\leq$ 2 pF |

Parallel damping resistance:

Dependent on voltage and frequency, between 10 kΩ and 200 kΩ

Measurements with probe PM 9203 and T-connector PM 9253.

| | | |
|---|---|---|
| Frequency range | 300 kHz...1200 MHz | |
| Accuracy | 700 kHz...1200 MHz | < + 5 dB<br>- 0 dB |

## RESISTANCE

| | | |
|---|---|---|
| Ω ranges | Full-scale values | 13.99 Ω, 139.9 Ω, 1399 Ω |
| kΩ ranges | Full-scale values | 13.99 kΩ, 139.9 kΩ, 1399 kΩ |
| MΩ ranges | Full-scale values | 13.99 MΩ, 139.9 MΩ, 1399 MΩ |

Accuracy

<u>For Ω and kΩ ranges</u>

| | |
|---|---|
| Relative to full-scale value | ± 0.2 % |
| Relative to reading | ± 0.2 % |

<u>For MΩ range below 100 MΩ</u>

| | |
|---|---|
| Relative to full-scale value | ± 0.3 % |
| Relative to reading | ± 0.2 % |

<u>For MΩ range above 100 MΩ</u> ± 2 %

<u>Current and voltage</u>

| range | max. current | max. voltage |
|---|---|---|
| Ω | 1 mA | 1.4 V |
| kΩ | 5 μA | 7 V |
| MΩ | 5 nA | 7 V |

Range selection

Range group with push-buttons, manually.

Three ranges within each group, chosen by means of automatic range selector; also manually adjustable

Temperature range for the stated accuracy $23^{\circ}C \pm 5^{\circ}C$

Temperatur coefficient (except for H. F. measurements) between $-10^{\circ}$ C. . . $45^{\circ}C$ $\leq 200$ ppm/$^{\circ}C$

Typical value $\leq 100$ ppm/$^{\circ}C$

| | | |
|---|---|---|
| Power supply | Mains voltage | 115 V and 230 V $\pm$ 15 % |
| | Mains frequency | 50. . . 60 Hz |
| | Power consumption | 22 VA |

Capacitance between mains and circuit zero < 50 pF

Capacitance between "LO" and chassis 0.1 μF

Permissible direct voltage between chassis and circuit zero max. 500 V

Analogue output

voltage per digit 5 mV

max. output voltage 7 V

source resistance 5 kΩ $\pm$ 0.25 %

Digital output

with additional printed circuit board PM 9221.

Mechanical data

| | | |
|---|---|---|
| Dimensions | Width 305 mm |
| | Height 145 mm |
| | Depth 270 mm |
| Weight | 7 kg. |

## III. ACCESSORIES

Mains lead

Fuse indication plate for mains voltage

Measuring cable, complete with one measuring probe holder, two measuring clips and measuring probe tip.

Manual

OPTIONALLY AVAILABLE

## HT probe GM 6070

This probe is suitable for measuring direct voltages up to 30 kV.

Maximum measuring error: 5 % (in conjunction with PM 2421).

Input resistance: 1000 MΩ

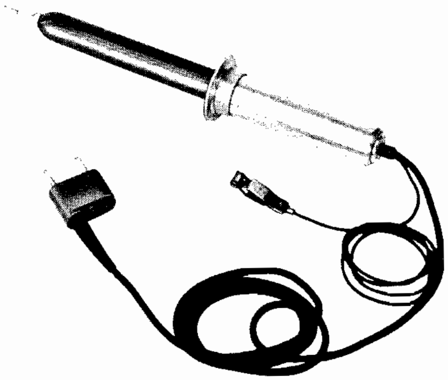


Fig. 1. HT probe GM 6070

## HF probe PM 9203

This is suitable for measuring alternating voltages from 2 mV up to 1.4 V

| | |
|---|---|
| Frequency response | 300 kHz...700 MHz |
| Frequency response deviation | 300 kHz...300 MHz $\leq$ 0.5 dB |
| | 300 MHz...700 MHz $\leq$ 1.5 dB |
| Accuracy | 500 kHz...300 MHz $\leq$ 1 dB } at voltages |
| | 300 MHz...700 MHz $\leq$ 2 dB } < 5 mV |

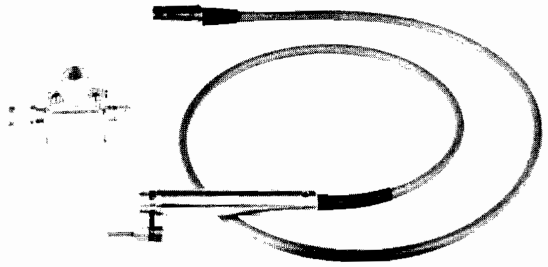


Fig. 2. HF probe PM 9203 and HF-T-piece PM 9253

| | |
|---|---|
| Input capacitance | $\leq$ 2 pF |
| Parallel damping resistance | 10 kΩ . . . 200 kΩ , dependent on voltage and frequency |

HF-T-piece PM 9253

| | |
|---|---|
| Inpedance | 50 Ω |
| Frequency response | 300 kHz. . . 1200 MHz |
| Accuracy | < + 5 dB |
| | < - 0 dB |

Digital output unit PM 9221

Printed circuit board with connector, for mounting on digital unit (U4). Outputs at 24-pòle Amphenol connector at the rear of the chassis for: result, polarity, range, measuring mode, transfer and inputs for stop/ start.

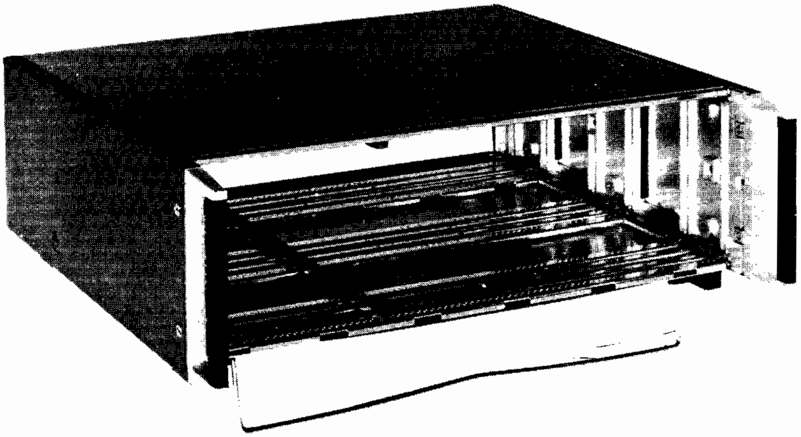


Fig. 3. Plug-in cabinet PM 9706

| | | | | |
|---|---|---|---|---|
| Output level | | | Output contact at CS2 and at U6 (PM 9221) | L ≙ > + 8 V/400 μA<br>0 ≙ < + 0.4 V/8 mA |
| | | | A B C D | |
| Output | Result | 1 | 1 2 3 4 | 13 BIT, from memory |
| | | 10 | 5 6 7 8 | BCD-Code (8-4-2-1) |
| | | 100 | 9 10 11 12 | |
| | | 1000 | 13 | |
| | Polarity | | 20 | 1 BIT + = L |
| | Range | | a b<br>17 18 | 2 BIT a,b |

| Range | a | b |
|---|---|---|
| 10 | L | L |
| 100 | O | L |
| 1000 | L | O |
| OVL. | O | O |

| | | | | |
|---|---|---|---|---|
| | Measuring mode | | ac dc<br>22 21 | 2 BIT ac, dc |

| Measuring mode | ac | dc |
|---|---|---|
| AC/HF | O | L |
| DC | L | O |
| Ohm | L | L |

| | | | | |
|---|---|---|---|---|
| | Transfer | | 19 | ≙ L. T = 50 μs<br>Appears at the end of the measuring cycle and can be employed for controlling a printer |
| Input | Stop<br>Start | | 23 | ≙ 0<br>≙ L (min. 1 μs, max. 95 ms for a single measurement) |
| | Circuit zero | | 24 | |

Note: The additional printed circuit board provides no galvanic isolation between the measuring circuit and the digital output; for operation with the automatic range selector an external control signal is required.

Plug-in cabinet PM 9706

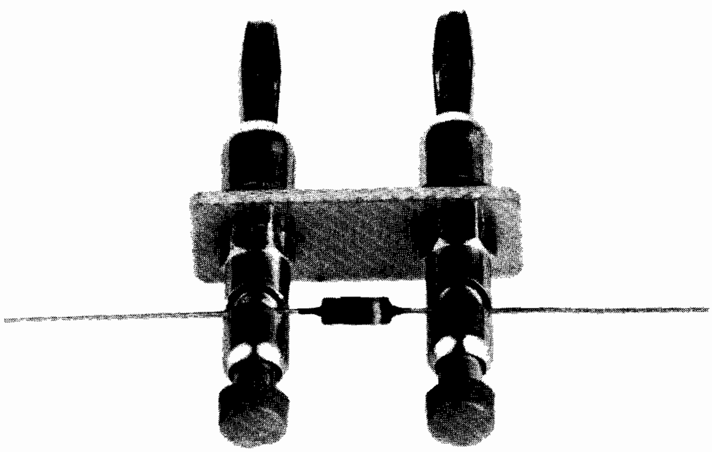
PM 9706 is a universal 3E-cabinet, with a width of 6 modules. It is provided with side panels including handles, feet, tilting bracket, top and bottom plate, guiding strips and a grey, plastic cable cover, in which two brackets are located for 19" rack mounting.

Blank panel PM 9722

PM 9722 is a blank panel for a 3E cabinet, having a width of 2 modules, to fill the blank space when the PM 2421 is mounted in cabinet PM 9706.

Blank panel PM 9721

PM 9721 is a blank panel for a 3E cabinet, having a width of 1 module. Two panels PM 9721 can be used instead of one PM 9722.



# IV. DESCRIPTION OF THE WORKING

## A. BLOCK DIAGRAM (Fig. 4)

Both the modes and the ranges are selected by means of push-buttons. Dependent on this selection, the functional untis are arranged so that an optimum measuring result is obtained. In this respect the following functions can be distinguished:

a. Arrangement of the functional units

The AC or DC amplifier, the direct current generator and the 300 kHz oscillator are connected to the appropriate input dependent on the mode of operation and are then connected to the anologue to digital converter. Various combinations are then possible (see under point B).
Moreover, in the case of a. c. and H. F. measurements, a low-ohmic voltage divider is included between the two a. c. amplifiers and in the case of d. c. and resistance measurements this divider is connected to the output of the d. c. amplifier.

b. Pre-selection of the measuring ranges

In the case of voltage or current measurements the input signals are matched to the inputs in accordance with the selected range. This pre-selection is effected in $10^3$ steps, such as e. g. for nA, μA and mA.

c. Auxiliary functions

The push-button switch performs various auxiliary functions such as short-circuiting the current terminals in the case of voltage and resistance measurements.
In the case of d. c. measurments it provides the polarity indication, and in the case of a. c. and h. f. measurements the sine symbol and it eliminates these signs in the case of resistance measurements.

### 1. D. C. amplifier

This amplifier serves for measuring direct voltages, direct currents and resistance values. In the case of H. F. measurements it operates as a very sensitive control amplifier.
This amplifier is chopper-stabilised and has a d. c. gain of more than $5 \times 10^7$.

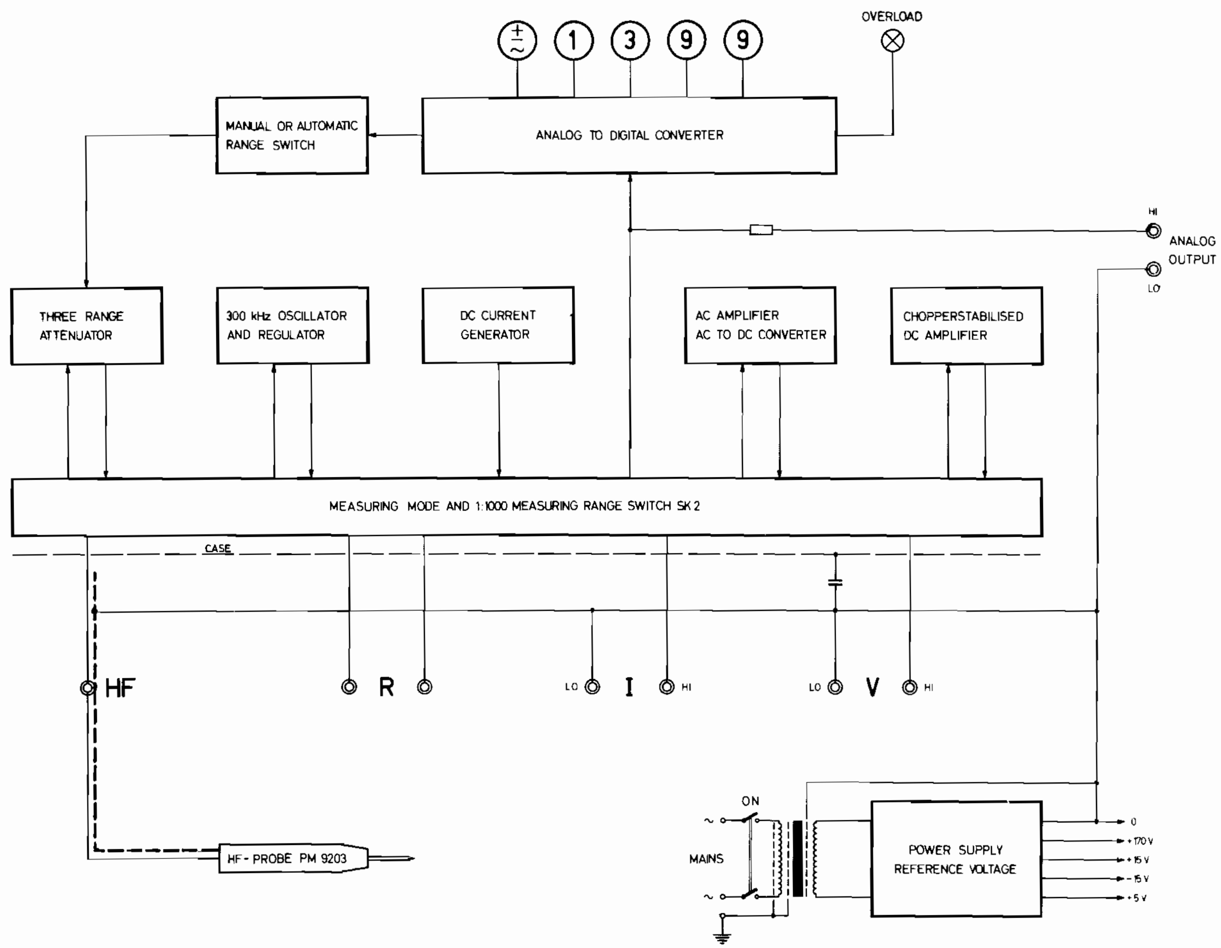



Fig. 4. Block diagram

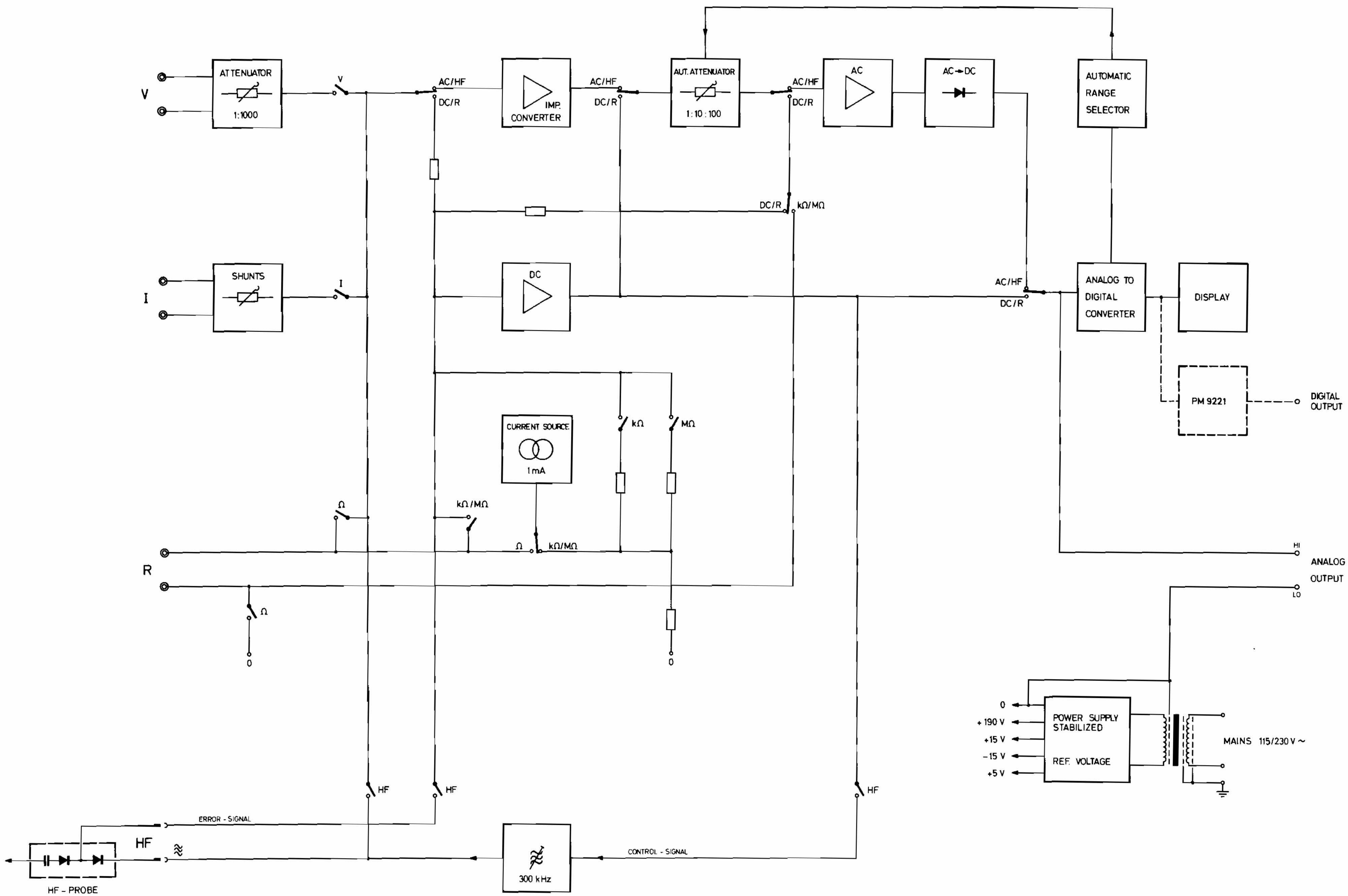



Fig. 5. Functional diagram

The chopper operates in series-parallel arrangement at 190 Hz and is equipped with cadmium-sulphide photo-conductors.

2. A. C. amplifier and a. c. -to-d. c. converter

The a. c. amplifier and the a. c. -to-d. c. converter are operative in the case of alternating current, alternating voltage and H. F. measurements. The first a. c. amplifier section is an impedance matching stage supplying the low-ohmic voltage divider.
The second voltage amplifier is followed by the a. c. to d. c. converter, which supplies an output voltage which is symmetrical with respect to earth. This direct voltage which is exactly proportional to the input a. c. signal, is converted in a d. c. difference amplifier into an output voltage, which is asymmetrical with respect to the circuit zero.

3. Current generator

The current generator supplies a constant direct current of 1 mA, which is employed for resistance measurements. To avoid long measuring times, the output voltage is limited.

4. H. F. section

The H. F. section comprises an L-C oscillator operating at 300 kHz. The 300 kHz output voltage is controlled by a regulator until it is equal to the H. F. voltage to be measured.
The principle of H. F. measurements is further described under point B. 3 of this chapter.

5. Voltage divider

Within the preselected coarse range voltage division is effeced in three decades. The low-ohmic voltage divider consisting of precision resistors, is automatically controlled by a reed relay.
The switching pulses for the relay are obtained from the digital section. Changing over to the relevant measuring range is effected automatically but manual operation is also possible.

6. Digital section

The analogue to digital converter coverts the analogue input signal into a digital signal. The digital information is first stored and then transferred to the display section. As long as the measuring value remains the same, the same value will be displayed. When the measuring value changes, the new value is displayed and is retained until the value changes again. When the measuring value is equal to or greater than 1400, the pilot lamp "OVERLOAD" indicates that the end-of-range value is exceeded.

7. Power supply

The stabilised supply circuits provide the voltages required for the various sections. The + 15 V and - 15 V direct voltages serve also as reference for the analogue to digital conversion.
All supply circuits are protected against short-circuiting and brief overloads.

B. FUNCTIONAL DIAGRAM

Fig. 5 shows the functional diagram. Dependent on the measuring mode the individual units are combined by means of the push-button switch.
A survey of the circuit arrangements for the various modes of operation is given below.

1. D.C. measurements (Fig. 6)

The 1: 1000 input attenuator divides the voltage in the measuring range "V" so that the output signal corresponds to that in the "mV" range and can be processed by the instrument. In the case of current measurements the voltage across the shunt resistor is measured.
The direct voltage measurement is based on the gain of a chopper-stabilised d.c. amplifier, which depends on the degree of feedback. The resulting analogue output signal is converted into a digital signal by means of an analogue to digital converter. A.C. interference superimposed on the measuring signal is suppressed by a low-pass filter. The signal on the input of the d.c. amplifier is inverted by this amplifier. The voltage amplification of the circuit depends practically only on the voltage divider

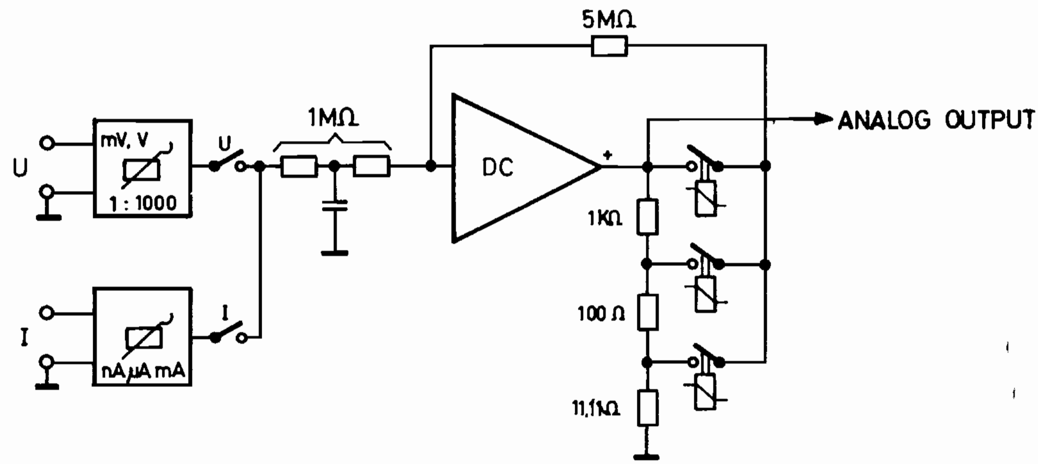



Fig. 6. D.C. measuring circuit

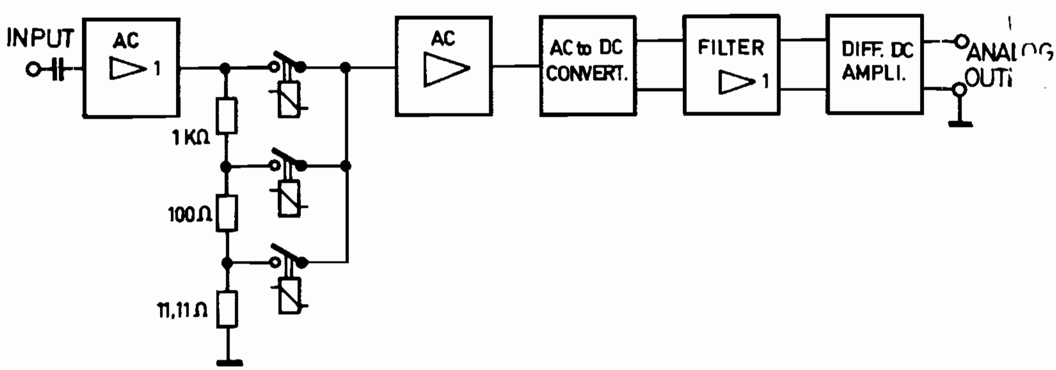



Fig. 7. A.C. measuring circuit

and the resistors in the feedback circuit, the internal amplification being very high.
At the "mV" ranges when the input signal is applied directly, the voltage gain is 5-times (upper relay contact closed), in the case of a 10:1 division (centre contact closed) it is 50 times, and in the case of 100:1 division (lower contact closed) it is 500 times.
An input voltage of 10 mV causes an analogue output voltage of 5 V at the highest sensitivity (gain factor of 500). This voltage corresponds to an indication of 10.00 in the digital section (button "mV" depressed).

2. A.C. measurements (Fig. 7)

The a.c signal to be measured is applied to the input of the impedance matching stage in the mV ranges. In the V ranges and in the current ranges the same voltage divider elements and shunts are employed as in the corresponding d.c. ranges. This means that in fact all a.c. measurments are reduced to voltage measurements at the mV ranges.
The d.c components are blocked by a capacitor at the input of the impedance matching stage. Alternating voltages are matched to a low output impedance in the impedance matching stage which has unity gain.
The voltage divider connected to the impedance stage is also employed for d.c. and resistance measurements, but in the case of a.c. measurements the sensitivity steps are reversed. As a result, the output voltage on the analogue output is 5 V d.c. when the upper contact is closed, if a sinusodial input voltage of 10 mV r.m.s is applied.
The voltage divider of the automatic range selector is followed by an a.c. amplifier with a high input impedance. The a.c. to d.c. converter comprises a wideband amplifier with a high no-load gain and a full-wave rectifier network included in the negative feedback circuit.
This results in average value rectification of high linearity. The output voltage of the a.c. to d.c. converter is symmetrical with respect to the circuit zero and will contain a.c. components.
Therefore, the signal is filtered and applied to an impedance matching stage. The following difference amplifier makes the signal asymmetrical with respect to the circuit zero, after which the value is determined by the digital section and the analogue output circuit.

3. H. F. voltage measurements (Fig. 8)

The H. F. voltage measurements are based on the compensation principle. For this purpose the amplitude of the voltage required for compensation is controlled so that the input and the compensation voltage have the same value. The measuring probe contains two pairs of diodes, one pair in the H. F. input circuit and the other pair in the compensation circuit. The direct current supplied by the diodes controls the d. c. amplifier which has a very high gain if there is no negative feedback. The output voltage of the d. c. amplifier controls the oscillator and the control amplifier of the latter so that the oscillator voltage which is used as compensation voltage becomes equal to the H. F. input voltage. The polarity of the rectified H. F. voltage is opposite to that of the rectified compensation voltage.

When the two voltages have the same value, the resulting d. c. output voltage will be zero. On the input of the a. c. to d. c. converter a 300 kHz signal arises, whose amplitude has the same value as that of the H. F. signal to be measured. This 300 kHz compensation voltage is measured by the digital section via the a. c. -to-d. c. converter in the same way as with a. c. voltages in the mV ranges.

Errors arising on account of the spead in tolerances of the rectifier diodes in the input circuit are practically eliminated by employing diodes with the same properties in the compensation circuit.

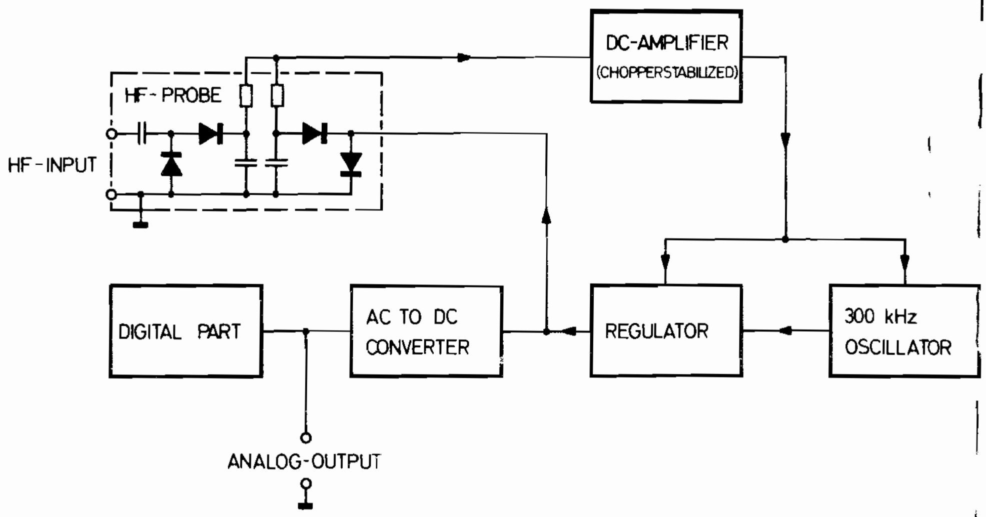



Fig. 8. Circuit for H. F. measurements

## 4. Resistance measurements

Resistance measurements at the Ω-ranges are effected by measuring the voltage drop across an unknown resistance. (Fig. 9). A current generator supplies a constant current of 1 mA flowing through the resistance to be measured. The voltage drop across the resistor is proportional to the resistance value and is measured by the direct voltage measuring circuit after which it is displayed.

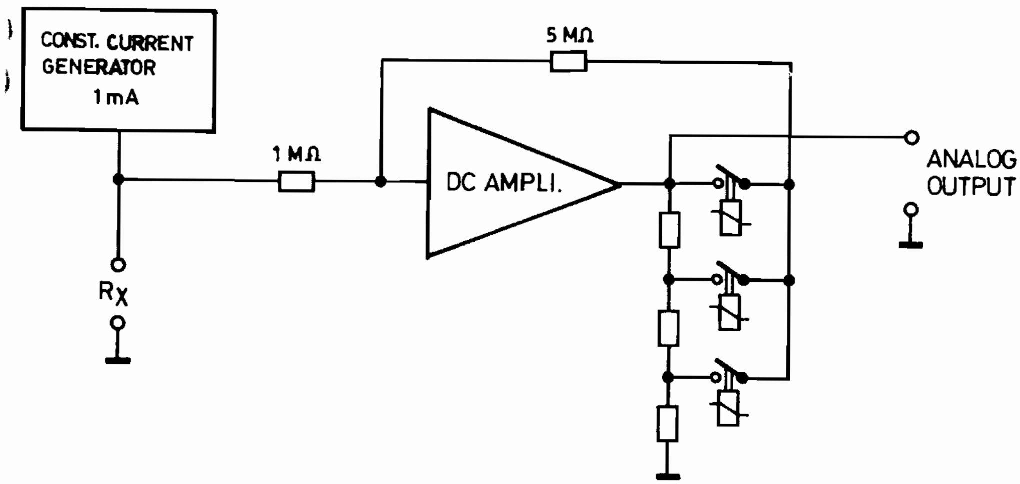



Fig. 9. Resistance measuring circuit in the Ω-range

At the kΩ and MΩ ranges the current from the current generator flows through a 10 Ω resistor (Fig. 10). As a result a 10 mV voltage source is obtained and the resistance to be measured which is included in the feedback circuit then changes the gain of the d. c. amplifier.

The voltage on the analogue output depends on the position of the voltage divider and is exactly proportional to the value of $R_x$. The drive circuit of the d. c. amplifier comprises resistor R1. The value of this resistor defines the kΩ and MΩ ranges, because the current through $R_x$ in the feedback circuit assumes the value determined by R1. The voltage on the output of the amplifier is measured by the analogue to digital converter and displayed.

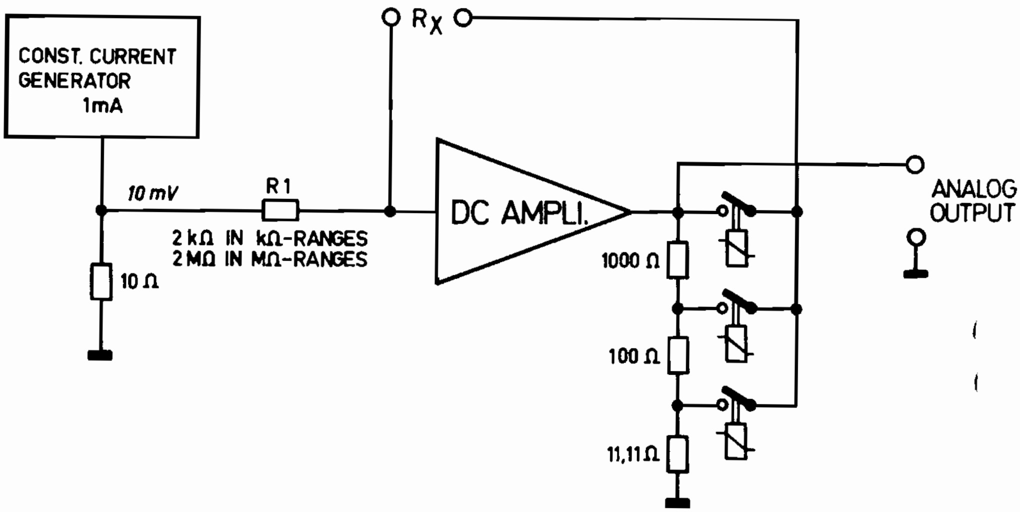



Fig. 10. Resistance measuring circuit in the kΩ and MΩ range

5. <u>Display section</u> (Fig. 11)

Conversion of the analogue signals into digital form is based on the dual slope principle in PM 2421.

The analogue input signal is applied to the integrator via series resistors and switching transistors.

The integrator supplies an output pulse whose width is proportional to the measuring value. The working principle of the integrator is described in more detail in the following chapter. Fig. 12 shows a graphical representation of the voltage as a function of time during the charging and discharging cycle.

During the integration process two main conditions should be distinguished which will be called upward integration (first step) and downward integration (second step).

During the first step (start) a current is applied to the integrator, which is proportional to the input voltage (S1 open, S2 and S3 closed). The output voltage of the integrator increases linearly as a function of time; its direction depends on the polarity, and its steepness on the value of the input voltage. The integration time is determined by the duration of 1000 clock pulses. During this interval upward integration is effected and capacitor C402 is charged.

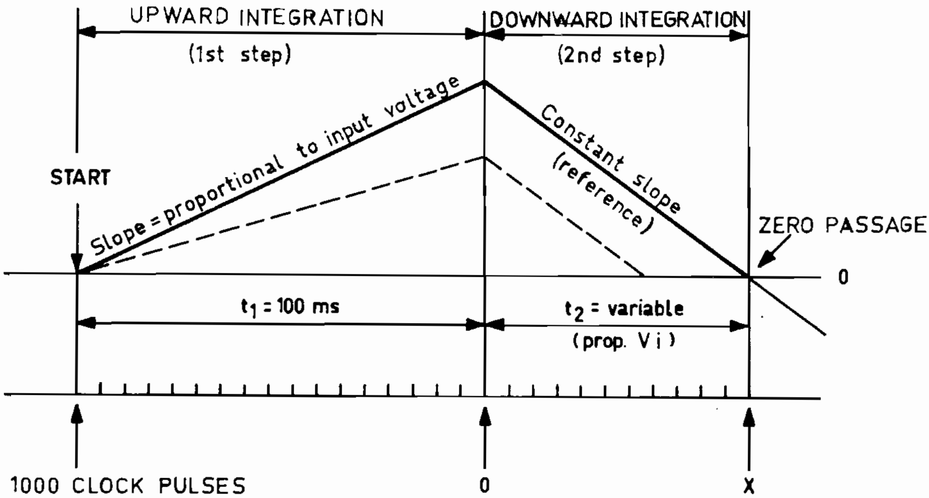



Fig. 12. Integration process

At the end of the first step the polarity of the integration voltage is determined and indicated. At this moment the counter supplies the transfer pulse, which initiates the downward integration and at the same time sets the counter to zero.

During the second step the integrator is discharged to zero by a constant current (S1 closed, S2 or S3 open, dependent on the polarity determined during the first step). The discharge rate is determined by the discharge current and, consequently, by the reference voltage, so that it will be constant. The time is measured by counting the number of clock pulses; it is directly proportional to the unknown input voltage applied during the first step.

As the same integration elements and clock generator are employed for both steps, temperature variations, long-term drift and absolute values will not affect the measuring accuracy.

The measuring accuracy in the first place depends on the accuracy of the reference voltage. Even without filters, this type of circuit is not sensitive to superimposed alternating voltages, because these are also integrated, i.e. the average value is determined.

As soon as the voltage on integrating capacitor C402 passes through zero during the discharge process, the gate is closed and the contents

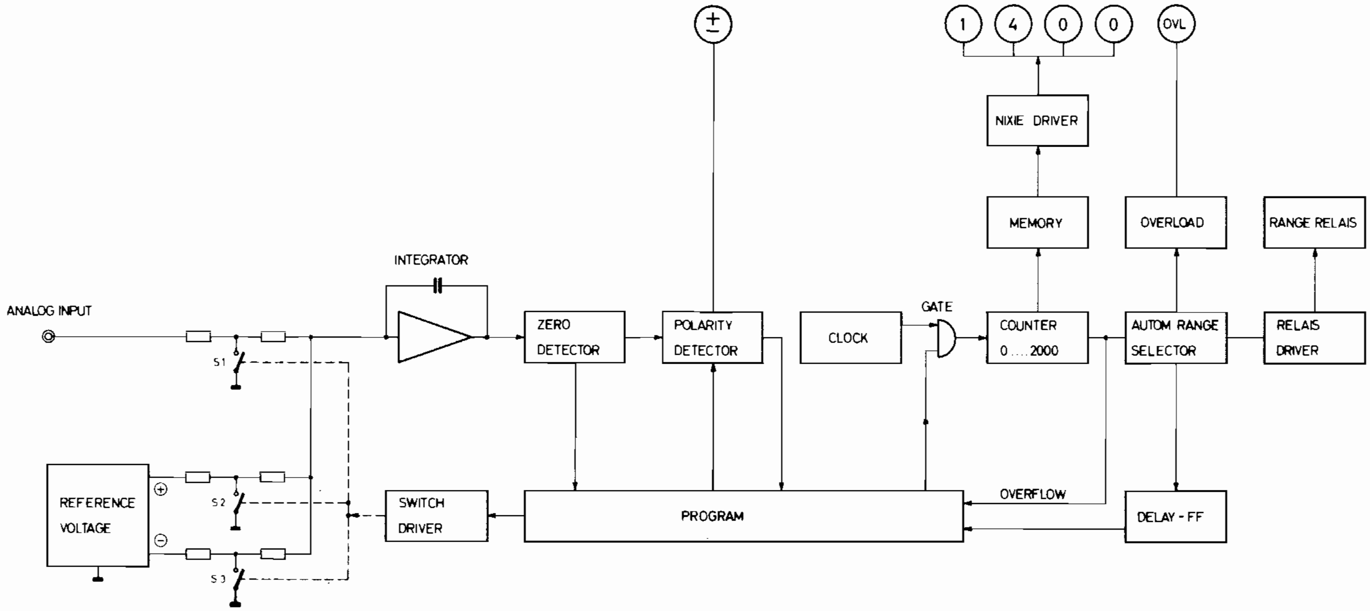



Fig. 11. Display section

of the counter is transferred to the memory and displayed. The counter also controls the automatic range selector, which has three different ranges. At a measuring value of more than 1400 units the next range is selected. When in the upper range the measuring value is again equal or more than 1400, pilot lamp "OVERLOAD" lights up and indicates that the measuring voltage has exceeded the permissible value and that the displayed result is no longer reliable. If an indication of 100 units is not obtained, the automatic range selector changes over to a more sensitive range. The selected range can be derived from the position of the decimal point. At each step of the automatic range selector the starting moment for the next measurement is delayed by 100 msec by the delay flip-flop. The pre-amplifiers of the a.c., d.c. and H.F. ranges are then adapted to the new measuring value during this delay.

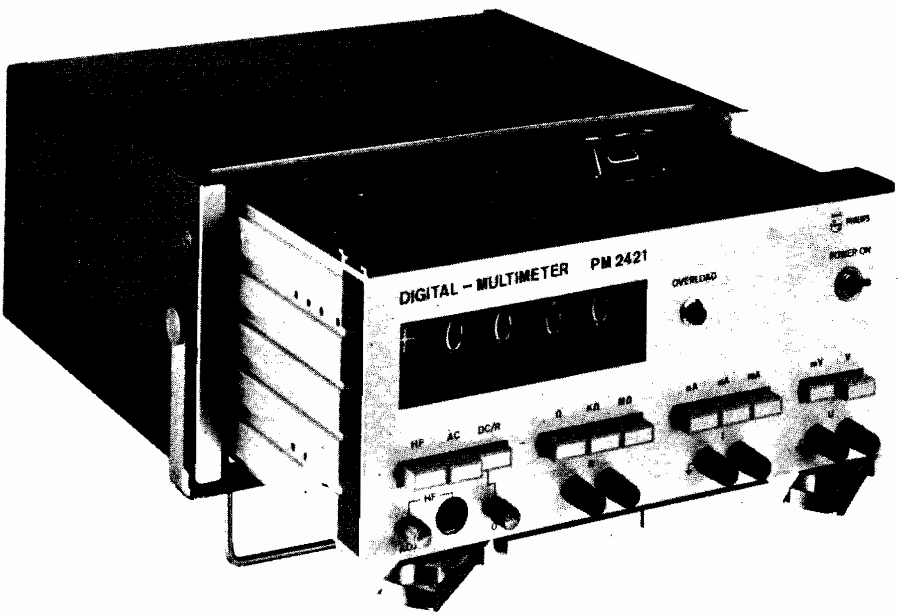



Fig. 13. Pulling the instrument chassis out of the cabinet

# INSTRUCTIONS FOR USE

## V. INSTALLATION

### 1. Adjustment to the local mains voltage

Before the instrument is put into operation, check that the instrument is adapted to the local mains voltage. The voltage to which the instrument is set in the factory, can be read on an indication plate at the rear of the instrument (220 V or 115 V). At these voltage values deviations of ± 15 % are permissible; fuse VL1 should have the following rating:

| Nominal value | Voltage range | Fuse VL1 |
|---|---|---|
| 230 V | 200...264 V | 160 mA delayed action |
| 115 V | 100...132 V | 250 mA delayed action |

Adjustment to a different voltage range is effected by resoldering the two jumpers on the mains transformer. For this purpose the chassis should be pulled out of the cabinet (caution, the instrument should not be connected to the mains) with the two locking devices (Fig. 13).
For the two voltage ranges the jumper should be connected as indicated in Fig. 14.

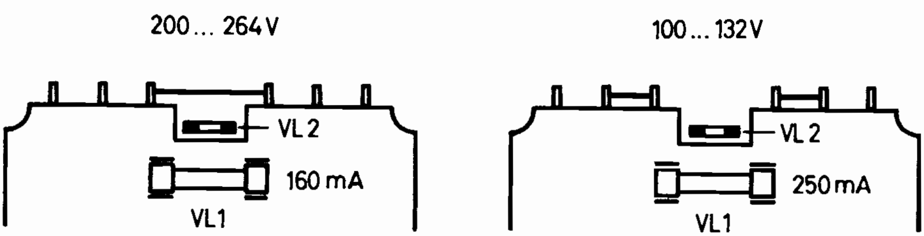



Fig. 14. Resoldering the jumpers on the mains transformer

When the instrument has been adapted to a new voltage value, the indication plate at the rear of the instrument should be changed accordingly.

Connection to the mains:

The instrument should be connected to a socket with rim earthing contacts by means of the three-core mains lead supplied with the instrument.

2. Earthing

For measuring technical reasons the housing and the circuit zero (LOW) have not been connected to safety earth so that they are floating.

If for safety reasons earthing of the instrument housing is desired (e.g. when measuring high voltages) the instrument may be earthed by means of a separate lead which should be connected to the earthing screw at the rear (Fig. 15).

Cabinet earth is not the same as the safety earth of the mains connection.

The instrument is equipped with a special mains transformer whose primary winding is enclosed by a screening on both sides. These screenings are connected to safety earth so that capacitive earthing currents from the primary winding are drained to safety earth via the screening.

The maximum permissible voltage between measuring input "LO" and the cabinet is 500 V d.c.

Furthermore, earthing should be effected in accordance with local safety regulations.

Combining the instrument with other modules

The chassis of the PM 2421 may be accommodated in a 6-module cabinet (PM 9706) instead of the 4-module cabinet. The additional space in this cabinet can then be used for other units of the 3E modular system, being employed in conjunction with a digital voltmeter or independently.

This 6-module cabinet is suitable for mounting in 19" racks. When the additional space is not used, it can be closed off by means of a blank plug-in chassis.

For converting the instrument into the rack mounting version, proceed as follows:

- Remove the grey, plastic cable cover from the PM 9706 cabinet and take out the brackets.
- Remove the four screws at the two sides.
- Slightly lift the side plates at the front and remove the plastic plates which are now accessible. The brackets can now be placed in the free space.
- Refit the side plates and secure them with the four screws.
- Remove the four feet
- Mount the desired number of guide rails to the upper and lower cross-bars. The appropriate holes in the crossbars are threated.
- Slide the PM 2421 out of the 4-module cabinet and slide it into the 6-module cabinet.
- Fill the free space with one unit PM 9722 or two units PM 9721
- Lock the PM 2421 and PM 9722.

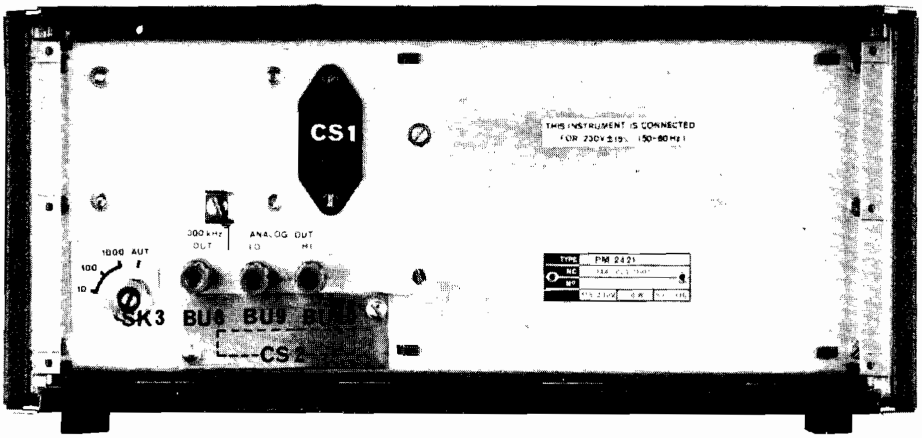



Fig. 15. Rear view

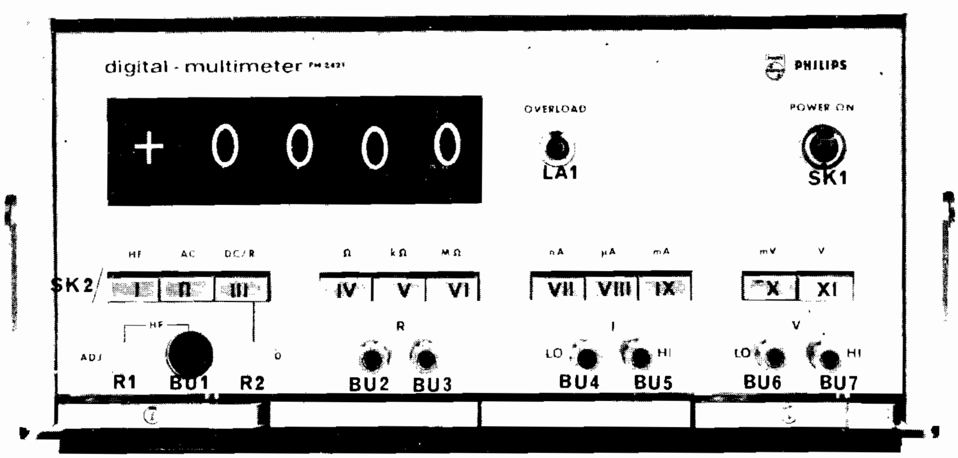



Fig. 16. Front view

# VI. OPERATION

## 1. Switching on

After connection to the mains and earthing, the instrument is ready for operation. By means of mains switch "POWER ON" the instrument is switched on; the display tubes light up. As no warm-up time is required, the measuring result can be read off immediately after selecting the desired mode of operation.

## 2. Mode selection

### Mode

The mode is selected by push-buttons, by means of which simultaneously the range group is selected in steps of $10^3$ i. e. 1:1, 1:1000 or 1:1000000. Within these pre-selected ranges, dependent on the measuring value, the instrument is automatically switched over to ranges with a ratio 1:1, 1:10 or 1:100, with corresponding display of the decimal point.
The modes d. c. and R (direct current, direct voltage measurements and resistance measurements) have a common push-button switch.

### Connection

For connection of the test circuit, separate sockets are available for voltage, current and resistance. Interaction between these circuits is impossible, because the push-button switches are interlocked. The left-hand "I" and "V" sockets are connected to the circuit zero and may be employed as LO (LOW).
For measuring H. F. voltages (> 1 MHz) the special H. F. probe (with T-connector for co-axial lines) should be employed. This probe must be connected to 5-pole socket "HF" on the front panel.

## 3. Measuring value display and measuring range selection

The measuring result is displayed by means of cold-cathode tubes, the decimal point being indicated by a spot in these tubes.
Changing over of the measuring ranges is effected automatically but may also be done manually.

Automatic operation

In the case of automatic operation the low-ohmic voltage divider receives switching commands which depend on the measuring value.
If the measuring value at the least sensitive ranges is 99 or less, a more sensitive range step is selected and if the measuring value is 1400 or higher a less sensitive position is selected, if possible.
This automatic switching process continues until either the indication lies between 100 and 1399 or until one of the two extreme range positions is attained. When the indication in the least sensitive range is 1400 or higher, pilot lamp "OVERLOAD" also lights up, because the guaranteed measuring limit of the relevant pre-selection range is then reached. At the most sensitive range the indication is also stable below 99. In the range between 100 and 140 the display is also retained if a higher accuracy would be possible for values between 1000 and 1300. This situation arises when the least sensitive position is switched on due to overloading or fluctation of the measuring quantity.
However, it is simple to force the automatic range selector to start the measurement at the most sensitive range so that an indication between 1000 and 1399 is obtained at coresponding measuring quantities,
In the case of voltage and current measurements it suffices to briefly switch on the higher coarse range by means of the corresponding push-button, or to interrupt the measuring circuit briefly. In the case of resistance measuremtns a brief short-circuiting of the R-sockets will cause the instrument to change over to the next, more sensitive range.

Manual operation

Manual range selection is more advantageous in the case of series measurements in a single range. For part of the measuring values the measuring speed is then increased, as the switching times are eliminated. The switch for manual selection is located at the rear of the instrument and can be operated by means of a screwdriver.

The switch has 4 steps: 1000, 100, 10 and AUTO. In position "AUTO" range selection is effected automatically, in the other positions the relevant ranges are switched on.

4. Polarity indication

In the case of d. c. measurements the polarity is indicated automatically on a cold-cathode tube with the + or - symbol. This indication refers to socket HI (High). In the case of resistance measurements the tube extinguishes and in the case of a. c. and h. f. measurements symbol "~" lights up.

5. The direct voltage measurement

For the d. c. mode push-button "DC/R" should be depressed. Up to input voltages of 1.4 V the "mV" button should be depressed and at higher voltages the "V" button. Before the measuring voltage is applied, it should be checked that the most sensitive measuring range is switched on; the position of the decimal point should be 00.00.
Control "0" serves for zero adjustment; it should be adjusted so that in the case of an open-circuited measuring circuit all digits are zero. After this the zero control should be set to a position at which the polarity reverses, i. e. at the +/- transistion.
When the voltage to be measured is applied to sockets "V" the measuring value and the polarity of the voltage are displayed.
When measuring very low voltages (below a few mV) it may be desirable to measure the voltage without the thermal voltage arising in the measuring lead. In this case zero adjustment should be effected after short-circuiting the measuring leads near the source. Thermal voltages in the measuring circuit can easily be compensated for with the zero control. After the adjustment and after removing the short-circuit the voltage source to be measured may be connected.

H. T. measurements

For measuring voltages between 1 kV and 30 kV H. T. probe GM 6070 is available. This probe should be connected to sockets "V", wherby the measuring pole should be connected to "HI" and the "⏚" pole of the plug to "LO".
The value indicated by the PM 2421 in the V-range should then be multiplied by factor 100.

Caution! Always connect the earthing wire of the probe to chassis or the zero pole of the h. t. source, before the high voltage is touched with the probe.

## 6. Alternating voltage measurements

The AC mode is selected with push-button "AC". With buttons "mV" and "V" the coarse voltage ranges can be selected; up to 1.4 V button "mV" should be depressed and at higher voltages up to max. 500 V, button "V". When connecting the voltage source to be measured, it should be observed that the potential which is closest to earth potential is connected to socket "LO". To avoid measuring errors the measuring lead should be connected so that no loop formation occurs. Capacitively induced currents from the mains will cause voltage drops in the measuring leads, which may affect the measurement.
The applied alternating voltage may be superimposed onto a direct voltage up to 400 V.
The instrument also permits of measuring voltages which are symmetrical with respect to earth. The housing of the measuring instrument should not be connected to earth in view of the capacitance between "LO" and "⏚"; the screenings should be connected to the circuit zero (LO)

## 7. Current measurement

In the case of voltage and resistance measurments sockets "I" are short-circuited and are connected to the circuit zero. For direct current measurements the "DC/R" button should be depressed and for alternating current the A.C. button. Dependent on the current to be measured, one of the three buttons "nA", "μA" or "mA" should be depressed. If the order of magnitude of the current to be measured is not known, it is recommended to start at the highest measuring range, i.e. mA. Otherwise the shunt resistors may be damaged.

The current circuit, especially in the case of AC measurements, should be connected so that the potential which is closest to earth potential is connected to socket "LO". In the case of alternating current measurements check that no earthing loops arise!
The voltage drop is 1 mV per nA, per μA or per mA, dependent on the selected range. If in the case of current measurments the voltage drop is of importance (at low internal resistance), the measurement may be effected in two different ranges. The influence of the different ranges can then be derived from the measuring result.
By means of corresponding separate shunt resistors it is possible to keep the voltage drop on the "I" sockets below 14.00 mV for all current values.

## 8. Resistance measurements

For measuring resistance values button "DC/R" should be depressed. Sockets R serve for connectiong the test object. By means of buttons Ω, kΩ, or MΩ the coarse range can be selected. The measurement is effected with the aid of direct current.
As a result, it is also possible to measure the resistance of coils and transformer windings.

Zero adjustement should be effected as follows:

Ω ranges:

At the Ω ranges sockets R should be short-circuited: The indication can then be set to 0000 with the zero control. When the resistance value of the measuring leads should not be included in the measuring result, the short-circuit should be made at the test object. If the indication is then set to 0000 with the DC zero control, the resistance of the measuring leads is compensated for within a small range.

KΩ and MΩ ranges

In these ranges the measuring arrangement is different (also see point II. B. 4). The zero adjustement then does not depend in the first place on the resistance value but on the gain.
Therefore, the "V" button should be depressed for zero adjustment. The indication should then be set to 0000 with the zero control.
After this release the "V" button again and depress the kΩ or MΩ button. In this case it is not necessary to short-circuit the R-sockets. At very low resistance values it should be taken into account that possible thermal voltages may affect the measuring result.
In such critical cases it is advisable to effect the zero adjustment procedure as described under "Ω ranges". The short-circuit should then be made direct at the test object and not at the sockets.
In the Ω ranges a current of 1 mA flows through the unknown resistance. On account of this it is also possible to compare semi-conductor as regards diode voltage and temperature drift at a forward current of 1 mA.
At higher resistance values (above 100 MΩ) the measuring time is relatively long on account of the low test current. Hum may then affect the measuring result. To prevent this it is recommended to screen the high-ohmic resistor, the screening being connected to the circuit zero, e. g. to socket LO of the I-input.

## 9. HF voltage measurements

For H. F. measurements at frequencies $\geq$ 1 MHz probe PM 9203 may be used and for measurements to co-axial lines T-connector PM 9253 is avaibable.
By means of the latter H. F. voltages with frequencies up to 1200 MHz can be measured.
The measuring probe should be connected to the 5-pole socket at the front of the instrument. The mode is selected with push-button H. F.
At voltages below 10 mV and in the case of large temperature variations calibration is necessary. For this control "ADJ" at the front and socket "300 kHz OUT" at the rear of the instrument should be used. The reference voltage available on socket "300 kHz OUT" serves for calibration.

Calibration:

- Switch on the instrument.
- Depress buttons "AC" and "mV".
- Connect socket "300 kHz OUT" at the rear to socket "V" — "HI" by means of a connection wire.
- Connect the HF probe to socket V-HI and connect the earthing wire of the probe to socket LO.
- Read the measuring result (observe a waiting time of approx. 20 sec).
- Depress button H. F.
- Accurately adjust the indication to the previous reading with potentiometer "ADJ".
- Fix the arrow of control "ADJ" so that the arrow points upwards in the calibrated condition.
- Disconnect the probe from socket V HI and remove the connection from socket "300 kHz OUT".

Usually this procedure will have to be carried out only once.
However, for H. F. measurements it should always be observed that the arrow of the control points exactly upwards, as the potentiometer is then in the calibrated position (provided that it has been correctly fitted during calibration).
Calibrated instruments should only be used in conjunction with the same probe as used for calibration. However, it is possible to calibrate several instruments with the same probe.

Measurement

Voltage measurements above 10 mV and at frequencies up to 300 MHz require no special measures. At low input voltage (below 5 mV) the indication is obtained rather slowly. Possible interference caused by H. F. fields may be eliminated by short-circuiting sockets V (HI and LO) and simultaneously connecting the R-sockets to LO of socket V.
For all HF measurements it should be observed that the housing of the probe is connected to a proper measuring earth by means of the accessory earthing lead. The earthing connection should be kept as short as possible; if necessary, screen the circuit (to prevent H. F. interference caused by radio transmitters).
For measuring voltages at high frequencies it is recommended to use the T-connector. This T-connector can be included in the test circuit by means of the co-axial cable with BNC connectors. The HF probe is connected to the H. F. leads by screwing it into the T-connector.
For measurements at the voltage range from 1.4 V.....140 V a capacitive voltage divider with a division ratio of 100:1 is provided. As this divider precedes the measuring diodes, the position of the decimal point will no longer be correct. Therefore, the indication in the mV range should be multiplied by 100.

10. Analogue output

In the analogue circuit all measuring voltages are converted into direct voltages of the same order of magnitude. The value of this direct voltage, within a certain range, is directly proportional to the input quantity and is 5 mV per digit; it follows that for the full-scale value of 1400 the output voltage will be 7 V. To prevent the indication from being affected in the case of short-circuiting of the analogue output, a 5.6 kΩ resistor has been connected in series with the analogue voltage source.
The analogue output is located at the rear of the instrument and the relevant sockets are marked "ANALOG OUT". Thus it is possible to use the PM 2421 as a sensitive d.c. amplifier and to record the measuring result with the aid of recording equipment.

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